

# **Seabed Variability and its Influence on Acoustic Prediction Uncertainty**

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## **LONG-TERM GOALS**

Assess the impact of seafloor variability on the uncertainty in predictions of the acoustic character of the seabed.

## **OBJECTIVES**

- (1) Use computer- and, where appropriate, laboratory-generated strata to forward model sea-bed acoustic properties (e.g., elastic moduli, velocity and attenuation) in a variety of littoral settings, and provide statistical measures of these modeled properties for use in simulating acoustic propagation and reverberation.
- (2) Generate synthetic seismic data of the computer- and laboratory-generated strata for use in testing high-resolution geoaoustic inversion methods.

## **APPROACH**

Shallow-water acoustic propagation is often strongly affected by interaction with the seafloor. The degree to which the propagation is modified by the seabed's acoustic properties is not well understood because the natural variability of these properties is difficult to thoroughly document. Process-based computer and laboratory models of shallow water strata offer two novel avenues for helping address this problem. The first is that these models provide predictions of the statistical distributions of the acoustic properties in different shallow-water settings. Secondly, these models can be used as "virtual" seabeds for constraining the impact of different but completely known mixtures of the properties on acoustic propagation and reverberation.

In this study, computer-generated and in certain circumstances laboratory-generated strata are being used to simulate acoustic properties and their impact on seismic/sonar data. The computer-generated strata are being modeled with SEDFLUX (Syvitski et al., 1999). The laboratory-generated strata are that formed in the Experimental Earthscape (XES) Basin at the St. Anthony Falls Laboratory of the University of Minnesota. SEDFLUX uses first principles of sediment transport to predict stratigraphic distributions of grain size. The model then uses empirical relationships to compute corresponding values for porosity, bulk density and permeability.

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We have developed a complementary set of models that use the SEDFLUX outputs to predict velocity and attenuation, and to simulate synthetic seismic data of the SEDFLUX strata. The SEDFLUX predictions of porosity, bulk density and grain size are used to compute elastic moduli via the empirical formulations of Kuster and Toksöv (1974), Berryman (1980a,b), Gassman (1951), and Xu and White (1995). These elastic moduli, along with the bulk density and permeability, are then used in the Biot (1962a,b) model to compute frequency-dependent velocities and attenuations. In turn, these properties are input to convolution and finite element models of seismic wave propagation that we have developed for simulating synthetic seismograms (e.g., Pratson et al., 2001).

## **WORK COMPLETED**

- Geoacoustic properties were modeled for SEDFLUX simulations of the New Jersey continental shelf produced by I. Overeem (INSTAAR).
- A two-dimensional finite-difference model of the wave equation was completed for simulating 2D synthetic seismograms that include the Biot (1962a,b) effects of frequency-dependent attenuation.
- Work with J. Syvitski and E. Hutton at INSTAAR continued on integrating the Duke physical property and synthetic seismic modeling codes with SEDFLUX.
- Working with C. Jenkins (INSTAAR), available physical property measurements have been compiled for the mid-eastern US shelf encompassing the GEOCLUTTER and PRIMER study areas (Figure 1).

## **RESULTS**

The geoacoustic properties modeled for sands in the New Jersey Shelf SEDFLUX simulations were found to be unrealistic. The high predicted porosity of the sands caused a breakdown in the Kuster-Toksöv /Differential Effective Medium method (Xu and White, 1995) for computing corresponding elastic moduli. This method is being re-evaluated and new methods for computing elastic moduli, as well as for computing velocities and attenuations, are being assessed. The latter include the approach of Buckingham (1997, 1998, 2000) for simulating velocities and attenuations from little more than grain size distributions.

The existing physical property measurements of the mid-eastern US shelf area (Figure 1) are now being gridded and converted into acoustic properties (principally bulk density, velocity and attenuation). These data will be provided to other DRI teams to give them a first-order estimate of the impact of the seabed on sound propagation in the PRIMER study area and the regional boundary conditions for the seabed acoustic properties within the GEOCLUTTER study area.

## **IMPACT/APPLICATIONS**

Once the problems in modeling elastic moduli for high porosity sands are overcome, the acoustic properties simulated from the SEDFLUX strata will be compared against those that have been measured and inverted for from acoustic measurements in the New Jersey shelf GEOCLUTTER area. If the comparison proves successful, i.e. the SEDFLUX simulated properties approximate the measured properties, it will demonstrate the viability of using such process-based stratigraphic simulations to predict the geoacoustic character of the seabed over large, potentially inaccessible areas with little a priori knowledge of the region. The predictions can then also be used to guide interpolation and/or extrapolation of existing seabed data in the region.

## RELATED PROJECTS

ONR EuroSTRATAFORM: Synthetic seismic modeling of flood-derived and storm-reworked strata offshore of river mouths as simulated in computer and experimental stratigraphic models.

## REFERENCES

Berryman, J.G., 1980a. Long-wavelength propagation in composite elastic media I. Spherical inclusions: *Journal of the Acoustical Society of America*, **68**, 1809-1819.

Berryman, J.G., 1980b. Long-wavelength propagation in composite elastic media II; Ellipsoidal inclusions: *Journal of the Acoustical Society of America*, **68**, 1820-1831.

Biot, M.A., 1962a, Mechanics of deformation and acoustic propagation in porous dissipative media: *Journal of Applied Physics*, **33**, 1482-1598.

Biot, M.A., 1962b, Generalized theory of acoustic propagation in porous dissipative media: *Journal of the Acoustical Society of America*, **34**, 1254-1264.

Buckingham, M.J., 1997, Theory of acoustic attenuation, dispersion, and pulse propagation in unconsolidated granular materials including marine sediments: *Journal of the Acoustical Society of America*, **102**, 2579-2596.

Buckingham, M.J., 1998, Theory of compressional and shear waves in fluidlike marine sediments: *Journal of the Acoustical Society of America*, **103**, 288-299.

Buckingham, M.J., 2000, Wave propagation, stress relaxation, and grain-to-grain shearing in saturated, unconsolidated marine sediments: *Journal of the Acoustical Society of America*, **108**, 2796-2815.

Gassmann, F., 1951, Elastic waves through a packing of sphere: *Geophysics*, **16**, 673-685.

Kuster, G.T. and Toksöz, M. N. 1974, Velocity and attenuation of seismic waves in two-phase media: Part I. Theoretical Formulations: *Geophysics*, **39**, 587-606.

Pratson, L.F., A. Stroujkova, and D. Herrick, 2001, Seismic simulations of buried channels on a continental shelf: *Proceedings of the AGU Chapman Conference on the Formation of Sedimentary Strata on Continental Margins*, Ponce, Puerto Rico, June 17-19, p. 40.

Xu, S., and White, R. E., 1995, A new velocity model for clay-sand mixtures: *Geophysical Prospecting*, **43**, 91-118.

## FY02 PUBLICATIONS

Pratson, L.F., A. Stroujkova, D. Herrick, F. Boadu, and P. Malin, *in press*, Predicting seismic velocity and other rock properties from clay/mud/shale content only: *Geophysics*.

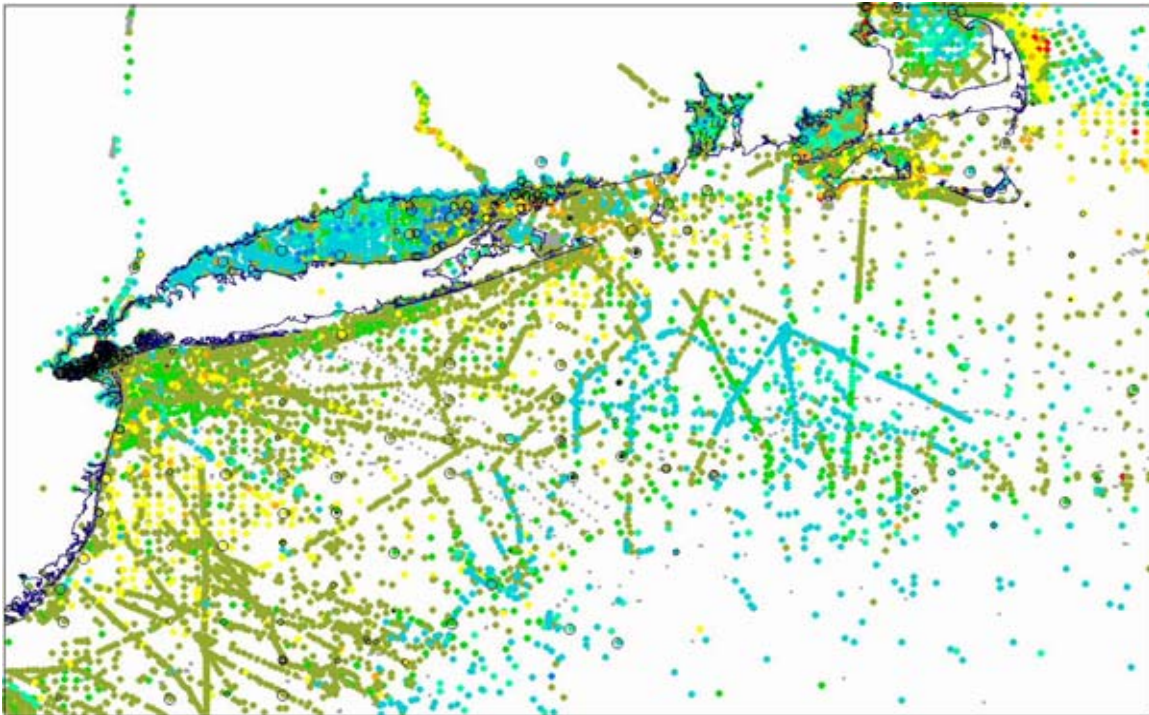
Pratson, L.F., and D. Cacchione, 2002 (abs), An open-ocean wide analysis of the slope of the continental slope and internal tides: *Eos Trans. AGU*, v. 83.

Cacchione, D., and L. Pratson, 2002 (abs), Internal waves and sedimentation on continental margins: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts*, v. 5.

Marr, J., and L. Pratson, 2002 (abs), Experimental study of subaqueous, clay-rich, gravity flows: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts*, v. 5.

Strong, N., J.J. Fedele, C. Paola, and L. Pratson, 2002 (abs), An experimental study at basin scale of valley incision and associated deposition during base-level fluctuations: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts*, v. 5.

Wolinsky, M.A., and L. Pratson, 2002 (abs), Overpressure development during siliclastic passive margin evolution: European Geophysical Society (EGS-AGU-EUG Joint Assembly, Nice, France, 4/6-11/2003), *Geophysical Research Abstracts*, v. 5.



**Figure 1. Distribution of core-derived grain size measurements, mid-east U.S. continental shelf and upper slope. [Warm colors are coarse-grained sediments (e.g., sands), cool colors are fine-grained sediments (e.g., clays). Image generated by C. Jenkins, INSTAAR.]**